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A COMPARISON OF DATA OBTAINED BY TWO FLIGHT TECHNIQUES

FOR DETERMINING THE SIDESLIP CHARACTERISTICS

OF A FIGHTER AIRPLANE

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A COMPARISON OF DATA OBTAINED BY TWO FLIGHT TECHNIQUES FOR DETERMINING THE SIDESLIP CHARACTERISTICS OF A FIGHTER AIRPLANE

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SUMMARY

In order to determine the validity of sideslip data obtained in flight by the continuous-record method, sideslip data obtained from a fighter airplane in slowly increasing sideslips have been compared with sideslip data obtained from the same airplane in sideslips in which all the flight conditions were stabilized. The results of the comparison showed no essential difference in the sideslip characteristics obtained by the two flight techniques even though the continuous sideslips were purposely executed with a yawing velocity about double the usual rate of 1° per second in order to accentuate the effects of the small yawing and rolling velocities inherent in the method. Approximate theoretical calculations confirmed the experimental results but indicated that rates of yawing or rolling lower than 1° per second are desirable if the continuous-sideslip technique is employed in testing airplanes much larger than current fighters. The method of measuring sideslip characteristics under steady conditions is preferred to the method of measuring sideslip characteristics in slowly increasing sideslips when the airplane is directionally unstable, when it has a large pitching moment due to sideslip, or when a poor relationship exists among the rudder, aileron, and elevator control forces in sideslips.

INTRODUCTION

From time to time questions have arisen concerning the validity of data on sideslip characteristics obtained by the continuous-record method as differentiated from the usual steady-record method. The usual flight technique

for measuring sideslip characteristics consists in taking records of control forces and angles under steady conditions of airspeed, heading, angle of bank, and angle of sideslip, at various attitudes of the airplane within the sideslip range to be covered. Although this method of testing obviously yields the desired results, it is uneconomical with regard to flight and instrument time consumed because only a relatively limited number of runs can be obtained in any one flight. In order to speed up the test program materially, sideslip characteristics have often been determined by the continuous-record method. This method consists in switching the recording instruments on at laterally level flight trim and then slowly moving the three controls together in such a way as to maintain constant airspeed and heading while causing the angle of sideslip or bank to increase at a slow rate (not exceeding 1° per sec) until one of the controls is fully deflected, or high control forces or other limitations are reached - at which time the instruments are switched off. The resulting data are handled under the assumption that the variables measured at any particular instant during the maneuver represent the steady sideslip values. The error of this assumption, of course, lies in the neglect of the small incremental control forces and deflections required to maintain the small angular velocities of the airplane during the sideslipping maneuver.

DESCRIPTION OF TESTS

In order to investigate the magnitude of the error involved in the continuous-record technique for determining sideslip characteristics, flight tests were made with a current fighter-type airplane (fig. 1) and sideslip data were recorded during the tests by both the steady-record and the continuous-record techniques. Sideslip records were taken at indicated airspeeds of 152 ± 3 miles per hour with normal rated power at about 5000 feet altitude. The slowly increasing sideslips were purposely executed with a yawing velocity about double the usual rate in order to accentuate the differences between the results obtained by the steady-record and continuous-record techniques. All control positions were measured at the control surfaces and the control forces were measured at the stick and rudder pedals.

RESULTS AND DISCUSSION

Results of the tests are shown in figure 2. These results indicate that very little error is incurred in sideslip-characteristics data because of the use of the continuous-record method. As would be expected, the test points obtained from the continuous records, when compared with the test points from the steady records, generally indicate that slightly greater rudder- and aileron-angle and control-force differences from the values corresponding to laterally level flight trim are required for a given sideslip angle. The slight discontinuity that appears in the curves where the direction of sideslipping is reversed is partly the result of the control deflections and forces required to accelerate the airplane from steady flight to the condition of small uniform yawing and rolling velocities. Control friction also contributes to the discontinuity in the control-force curves. Inasmuch as the continuous records of figure 2 were obtained for a yawing velocity approximately twice as great as the recommended maximum rate for fighter-type airplanes (1° sideslip per sec at low airspeeds), it becomes evident that, for the size and flight speed of the airplane tested, the discrepancy to be expected between sideslip data obtained by the two methods is within the scatter to be expected from successively repeated tests made by either of the methods.

Approximate theoretical calculations have been made of the variation of rudder-angle and total-aileron-angle errors with service indicated airspeed for the same fighter airplane in slowly increasing sideslips. Only the two most important yawing or rolling derivatives were considered in calculating the rudder or aileron error, respectively. For the rudder-angle error, these derivatives are the rate of change of airplane yawing-moment coefficient with yawing velocity due to the vertical tail and the rate of change of yawing-moment coefficient with rolling velocity due to the wing. For the total-aileron-angle error, these derivatives include the variation of wing rolling-moment coefficient with rolling velocity and the variation of wing rolling-moment coefficient with yawing velocity. Values for the wing derivatives were determined from the charts of reference 1. Vertical-tail effectiveness was estimated from reference 2. Aileron effectiveness was obtained from previous flight tests on the same airplane and from the theoretical charts of

reference 3. The side-force characteristics of the fighter airplane used were assumed to be similar to those measured for another fighter airplane having nearly identical geometric and weight characteristics. This assumption was necessary because no data were available for the airplane used in the tests from which to determine the ratio of rolling velocity to yawing velocity as a function of speed in properly executed sideslips. The errors were calculated both for a constant rolling velocity of 1° per second at all speeds and for a constant yawing velocity of 1° per second at all speeds. In practice, the rate of executing continuous sideslips is generally set by limiting the rolling velocity to roughly 1° per second at high speeds and by limiting the yawing velocity to about 1° per second at low speeds.

Results of the calculations for errors in rudder and aileron angles caused by use of the continuous-record method with the fighter airplane tested are presented in the curves of figures 3 and 4, respectively. The errors are given as functions of service indicated airspeed. A positive error indicates that more control deflection from the initial trim condition is required in a slowly increasing sideslip than in a steady sideslip. As noted previously, the rate of executing continuous sideslips is controlled by limiting the rolling velocity at high speeds and by limiting the yawing velocity at low speeds. An inspection of the calculated curves indicates that, if neither the rolling nor the yawing velocity were allowed to exceed 1° per second, the error in rudder-angle measurements should not exceed 0.2° at 100 miles per hour service indicated airspeed and should nearly vanish at high speeds; similarly, the error in total-aileron-angle measurements should not exceed 0.6° at 100 miles per hour service indicated airspeed and should become much less at high speeds.

If the rates of yawing and rolling and the airplane speed are held constant and the airplane size is increased, the errors in rudder-angle and aileron-angle measurements in continuous sideslips increase. Errors relating to the wing yawing or rolling derivatives increase in direct proportion to the increase in wing span, whereas the rudder-angle error due to vertical-tail damping increases in direct proportion to the increase in distance between the center of gravity and the vertical tail. Hence, if the continuous-record method for determining sideslip characteristics is used in testing airplanes much larger

than current fighter types (span, approximately 40 ft; vertical-tail length, approximately 20 ft), the maximum allowable rates of yawing or rolling probably should be reduced below the 1° per second limit recommended herein.

It is desirable to use the steady method for measuring sideslip characteristics for any flight condition if the relationship among the various control forces is poor, if the airplane is directionally unstable, or if there is a large pitching moment due to sideslip present. When none of these objectionable conditions are present and when continuous-recording instruments are available, the continuous-record method for determining sideslip characteristics can be used advantageously to save time in flight testing.

CONCLUDING REMARKS

The continuous-record method for measuring sideslip characteristics in flight yields accurate results for current fighter airplanes if the rate of yawing or rolling is not allowed to exceed 1° per second; lower rates of yawing or rolling are desirable if the continuous-sideslip technique is employed in testing larger airplanes in sideslips. When the relationship among the various control forces in sideslips is poor, when the airplane is directionally unstable, or when the pitching moment due to sideslip is unusually large, the steady-record method for determining sideslip characteristics is preferable to the continuous-record method.

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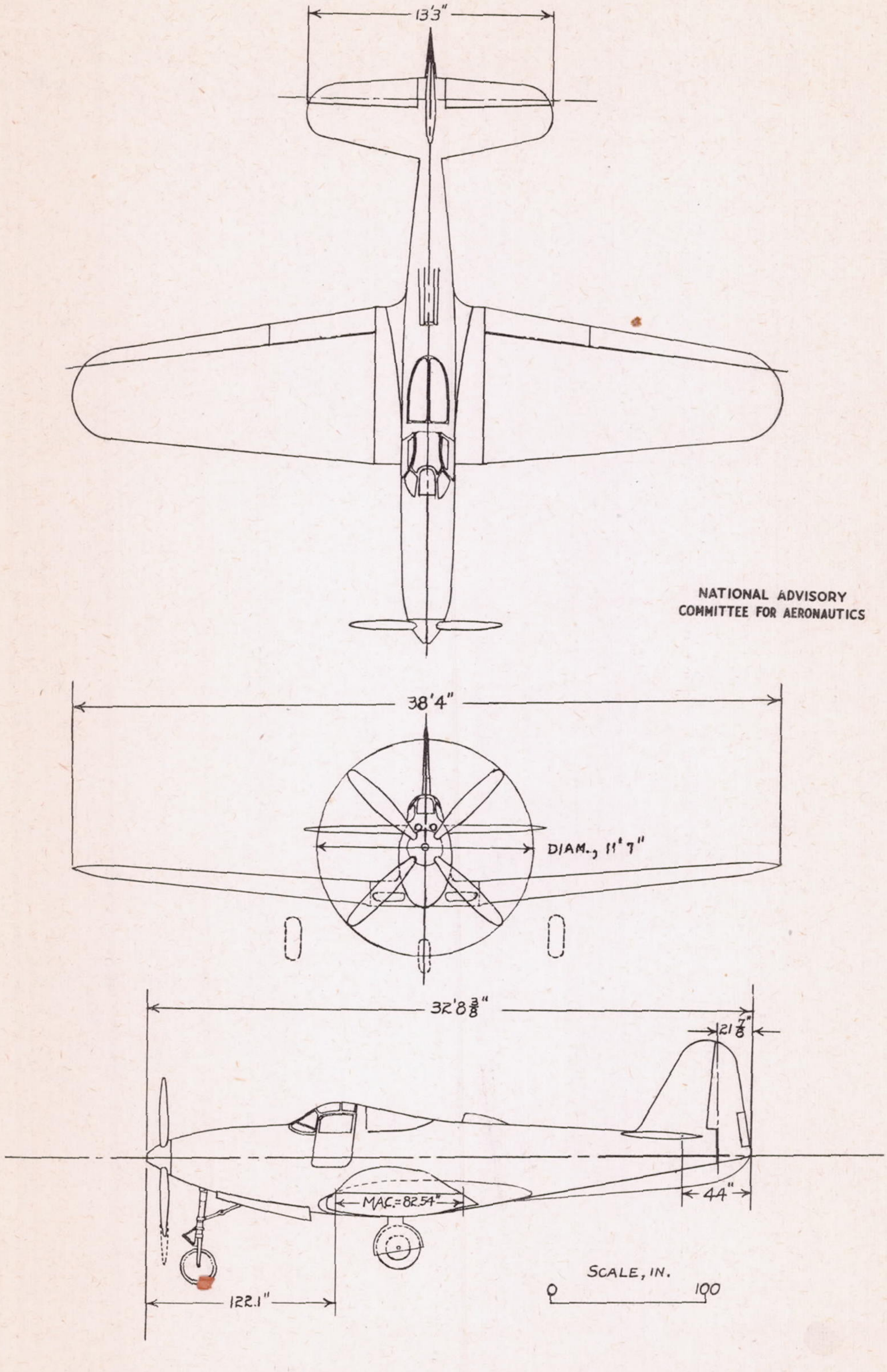

Figure 1.- Three-view drawing of fighter airplane used in the tests.

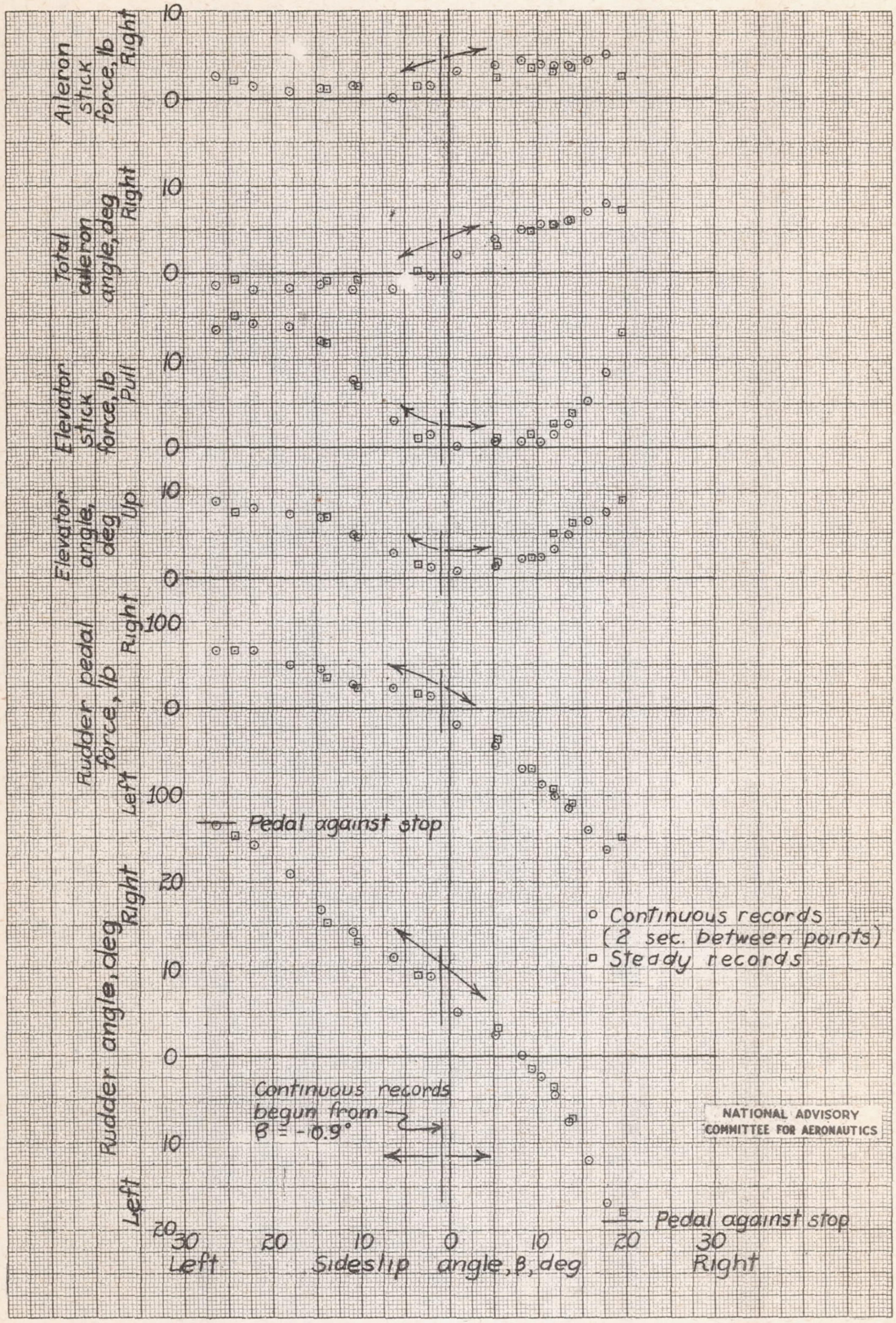

Figure 2.- Comparison of data obtained in continuous and steady sideslips. Current fighter-type airplane; normal rated power; indicated airspeed, 152 ± 3 miles per hour; altitude, approximately 5000 feet.

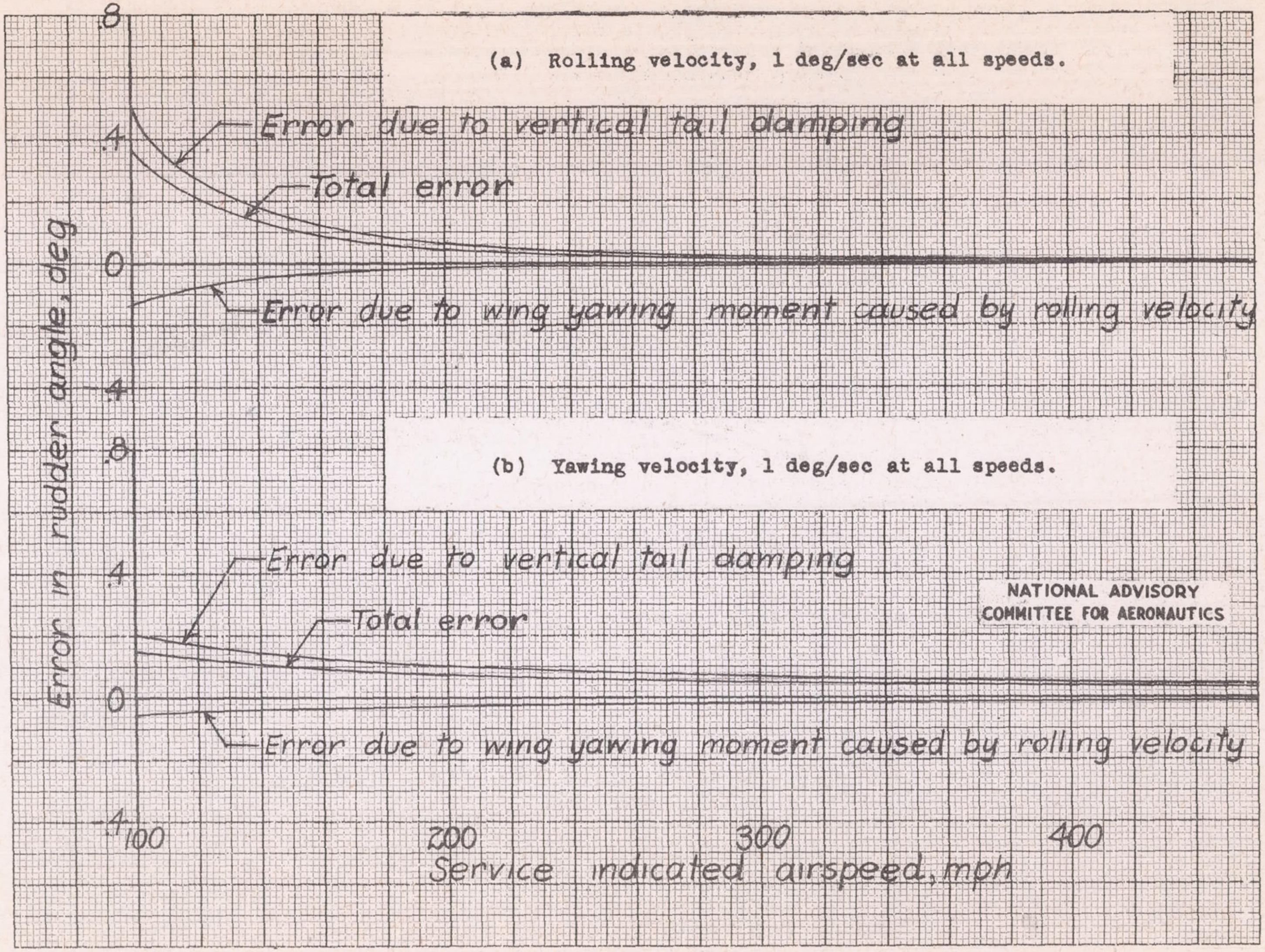

Figure 3.- Calculated approximate error in rudder angle as a function of service indicated airspeed in slowly increasing sideslips. Current fighter-type airplane; gross weight, 8000 pounds; wing area, 248 square feet; sea-level standard density condition.

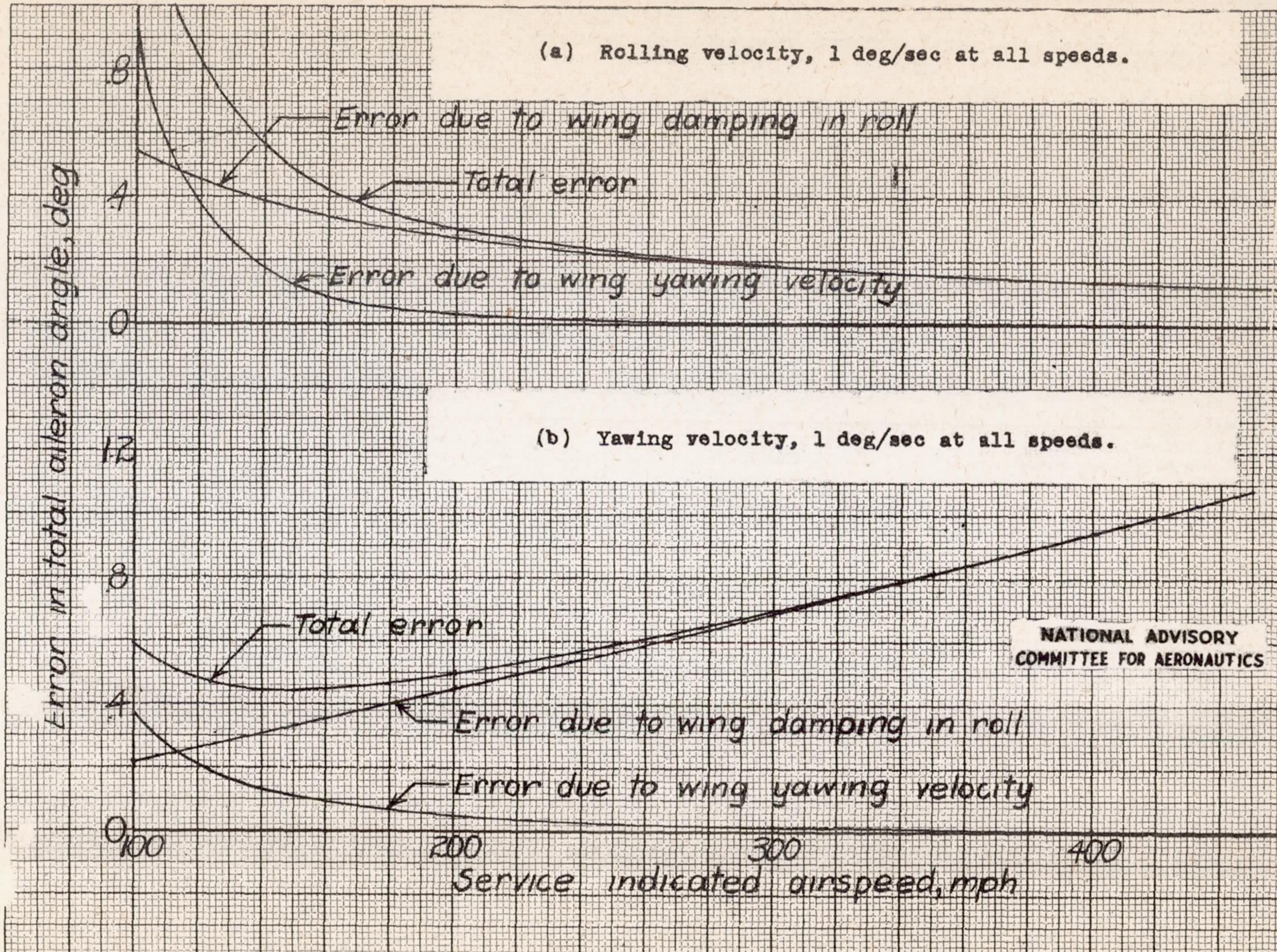

Figure 4.- Calculated approximate error in total aileron angle as a function of service indicated airspeed in slowly increasing sideslips. Current fighter-type airplane; gross weight, 8000 pounds; wing area, 248 square feet; sea-level standard density condition.